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Automating Forecasting and Exploration of Complex Simulation Effects (AFECSE)

June 10-12, 2008

LOCKHEED MARTIN

Thaddeus Konicki,
Janet Wedgwood, Zach Horiatis,
and John Welsh
Advanced Technology Laboratories

Introduction

- **Problem / Challenge**
  - Military planners are moving to Effects-Based Operations (EBO) to achieve desired effects through a combination of diplomatic, informational, military, and economic (DIME) actions
  - Modeling and simulation can be used to determine the probable desirable and undesirable effects of DIME actions, while developing a better understanding of second- and third-order effects
  - Currently, modeling and simulation environments for EBO are difficult and costly to develop and maintain

Discussion: Today's Modeling Approaches

- **Most modeling approaches focus on studying a problem in a specific domain that**
  - **Enable us to explore the intricacies of the subject domains**
  - **Ignore cross-domain dependencies and dynamics**
  - **Are typically based on a single modeling paradigm (discrete event, continuous time, or agent-based, etc.)**
- **Attempts to create models that try to incorporate all aspects in a single model have not been widely accepted**

Discussion: Benefits of Multi-Paradigm Modeling

- Most models are based on a single modeling paradigm (discrete event, continuous time, or agent-based, etc.)
- People who develop domain and paradigm specific models generally choose the best approach to solve the particular problem in their domain
- A single modeling paradigm may not be able to efficiently handle and represent all aspects of a complex realistic problem

Goal

- **Enable analysts to easily exploit the power of Modeling and Simulation for exploring Effects-Based Operations through automation of scenario development, model instantiation, integration and initialization and Course of Action (COA) development**

Approach

- **Automate the instantiation of a scenario**
  - **Represent the platform-independent description of an integrated model set in such a way that an autocoding tool/wizard can generate the simulation platform specific model integration code**
    - » Apply ontologies and a system modeling language to capture the relationships between the entities that are being models and the interactions that occur amongst the entities
    - » Parse and reason about the descriptive information found in the platform-independent descriptions to auto-generate the integration and execution control code

Ontology Language for Entity/ Model Relationships

- An ontology defines a set of representational primitives that can be applied to model a domain of knowledge or discourse.
- OWL = Web Ontology Language
- The principal technologies of the Semantic Web fit into a set of layered specifications: RDF Core Model, RDF Schema Language, OWL
- Semantic Web languages use XML syntax
- OWL vocabulary includes a set of XML elements and attributes with well defined meanings
  - Used to describe domain terms and their relationships in an ontology
  - OWL vocabulary is built on top of the RDF(S) vocabulary
  - Has a richness for describing relations among classes, properties, and individuals

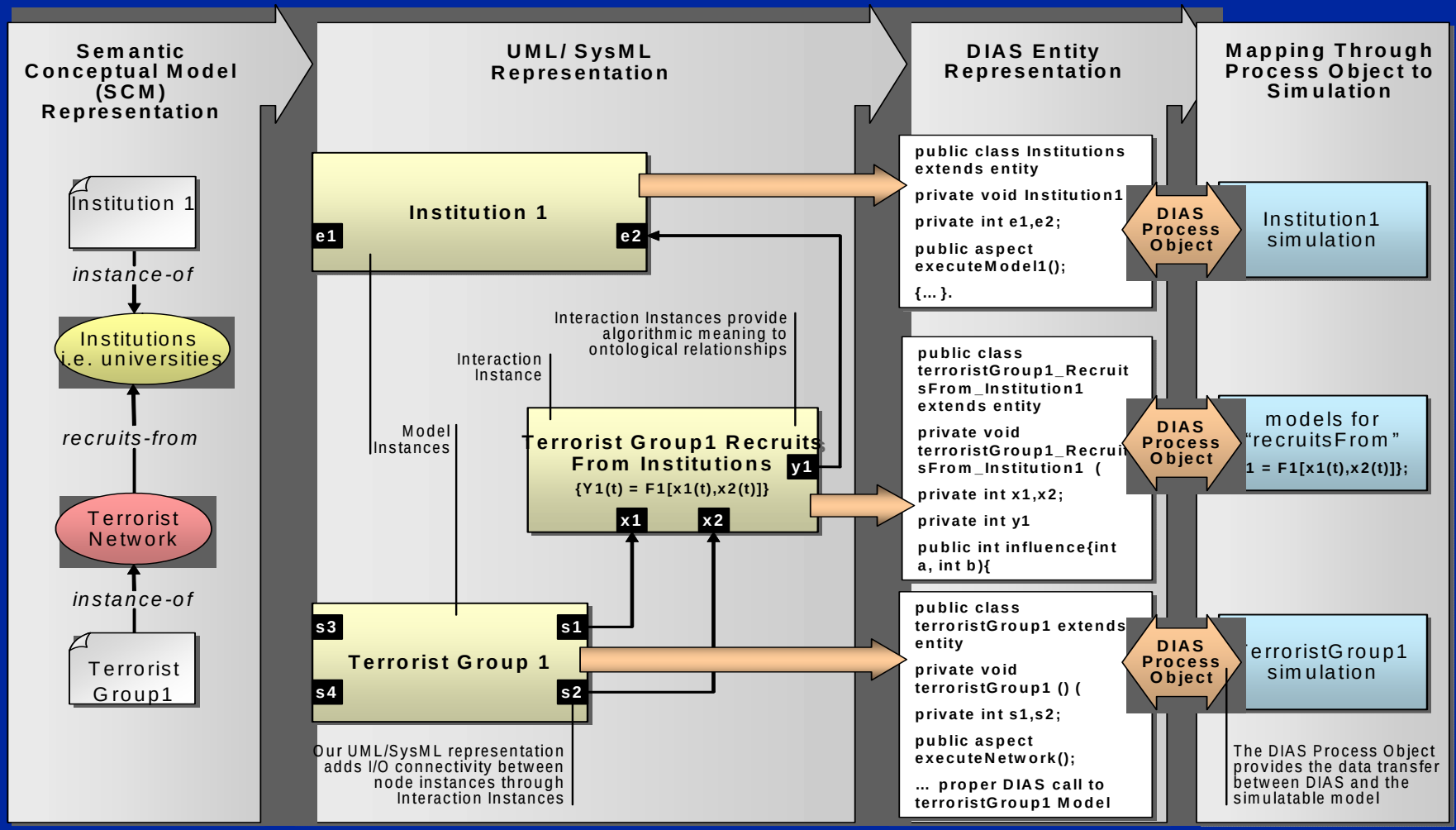
Apply OWL/RDF(S) to describe the relationships between the entities of a simulation and the models that represent them

UML/SysML for Integrated Model Interactions

- SysML is a visual modeling language for system engineering
- SysML extends, and is compatible with, the Unified Modeling Language (UML) for software engineering
- SysML reuses UML2 diagrams for
  - Use Case Diagram
  - State Machine Diagram
  - Interaction (Sequence) Diagram
- SysML extends the following UML2 diagrams
  - Block Definition Diagram (based on UML2 Class Diagram)
  - Internal Block Diagram (based on UML2 Composite Structure Diagram)
  - Activity Diagram (based on UML2 Activity Diagram)
- Adds the following diagrams
  - Requirements
  - Parametric Constraint

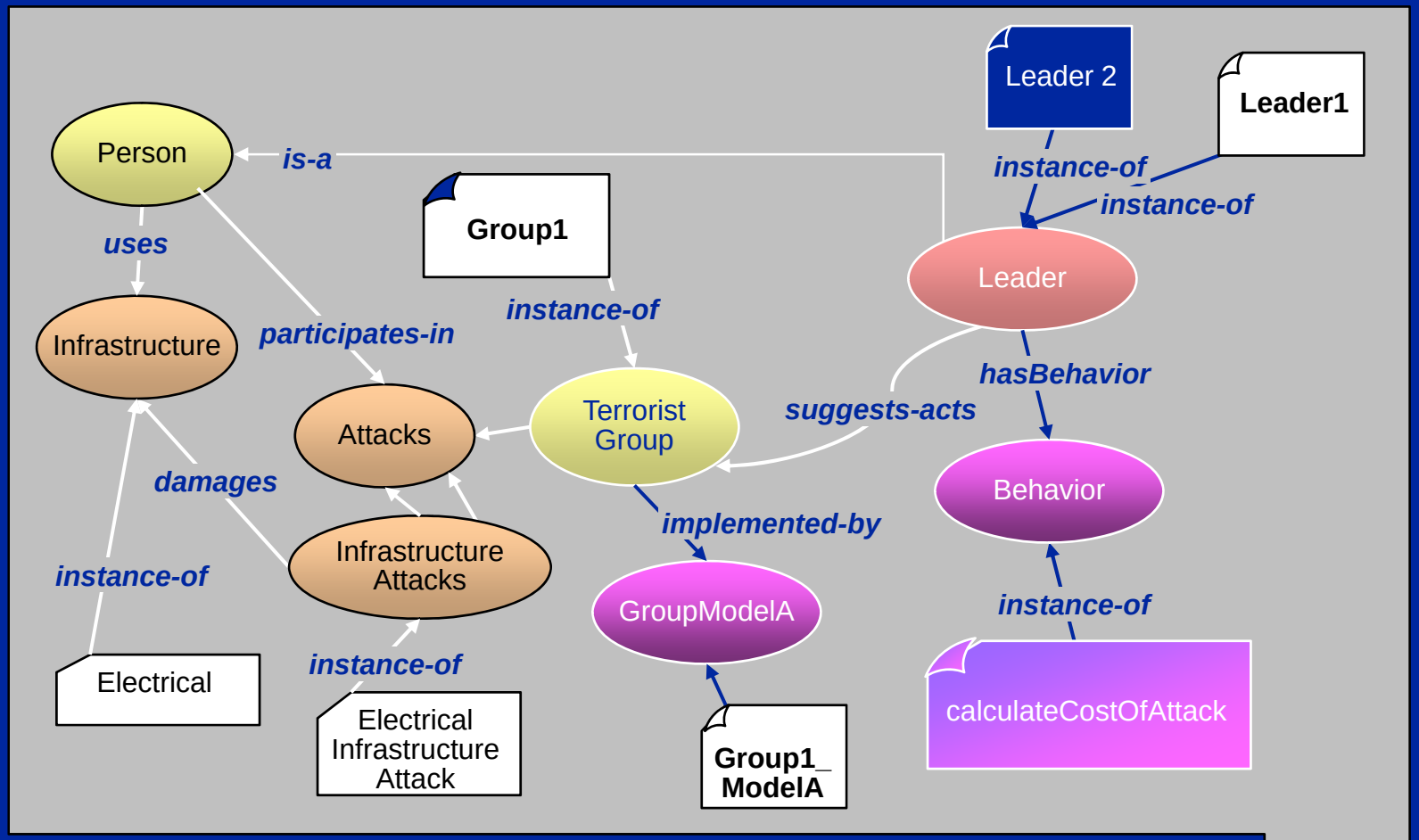
Use SysML constructs to capture data flow and interactions between the models

Integration Assistant for Simulation Instantiation



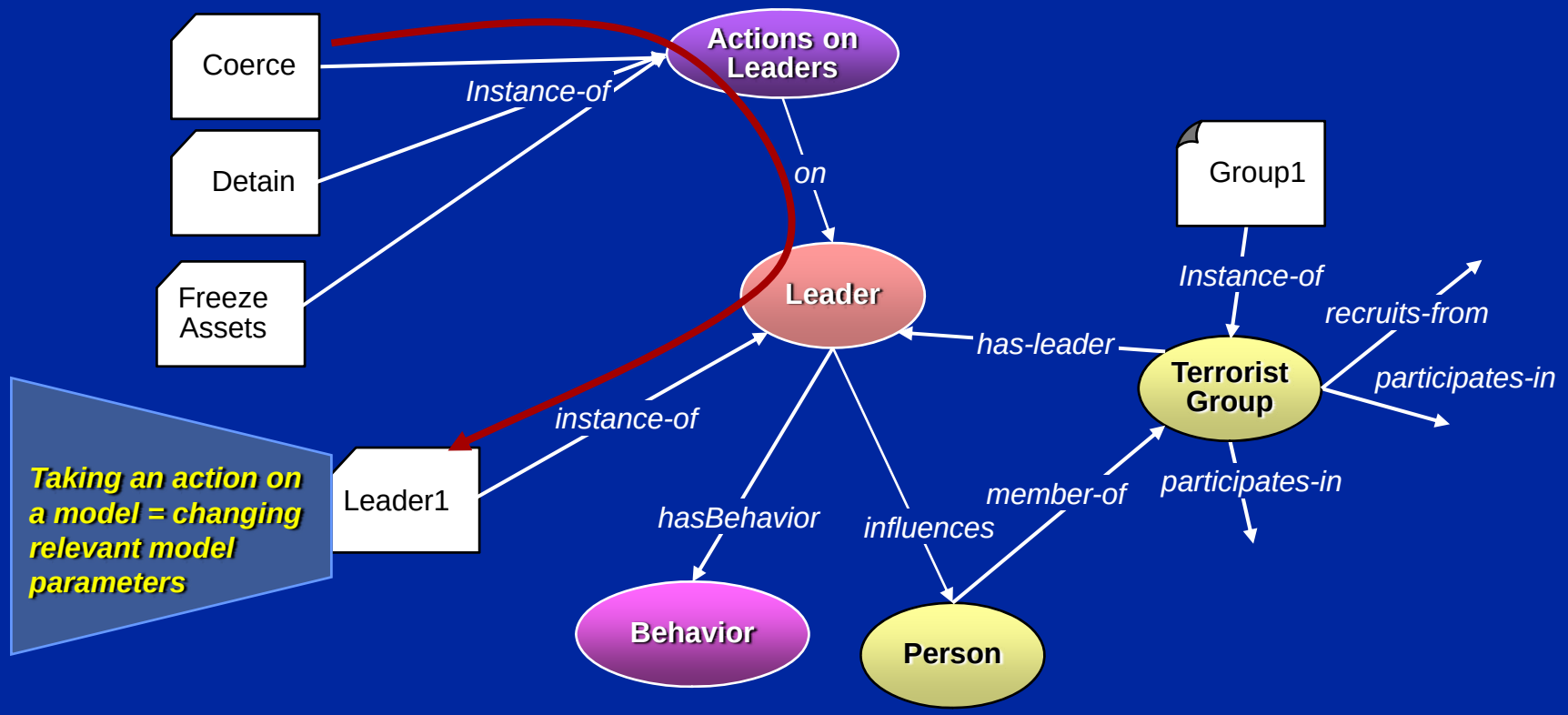
SimS combines ontological, structural, and behavioral representations of models to enable autocode assisted integration

Semantic Conceptual Model Example PIM



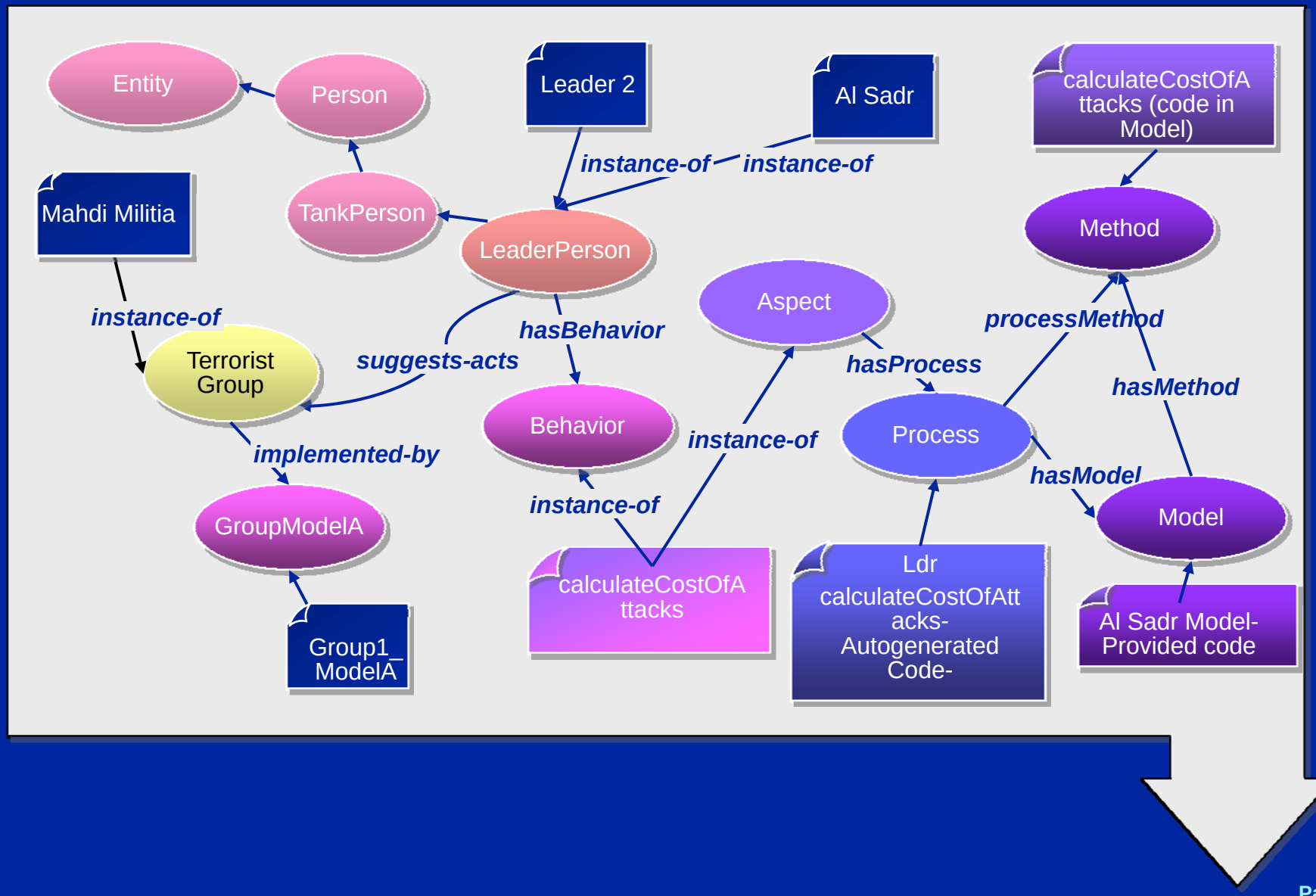
Our **Simulatable Scenario (SimS)** Enables Mapping of Semantic Models to Simulation Experiments

Conceptual Models with Actions

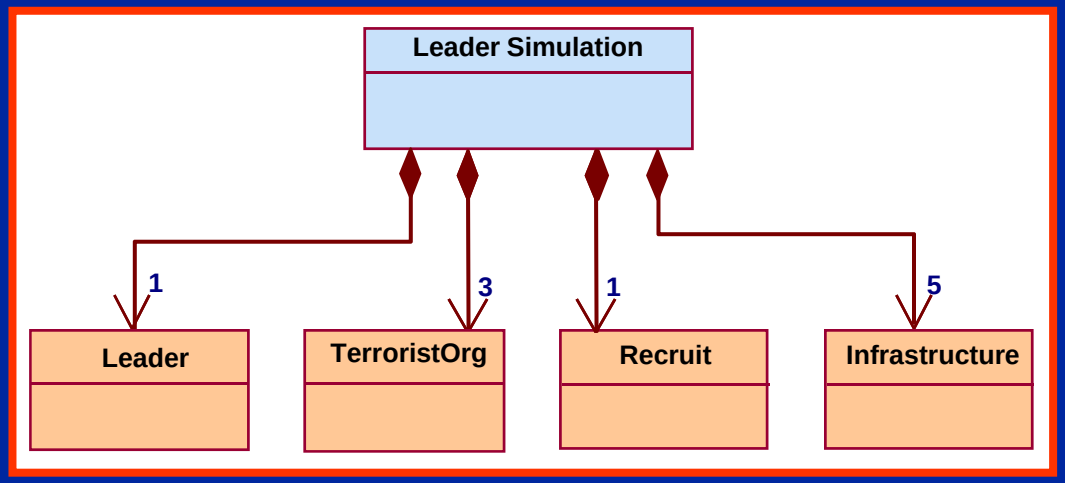


The conceptual model takes on new dimensions to support autocoding requirements

PIM-PSM Model Relationship



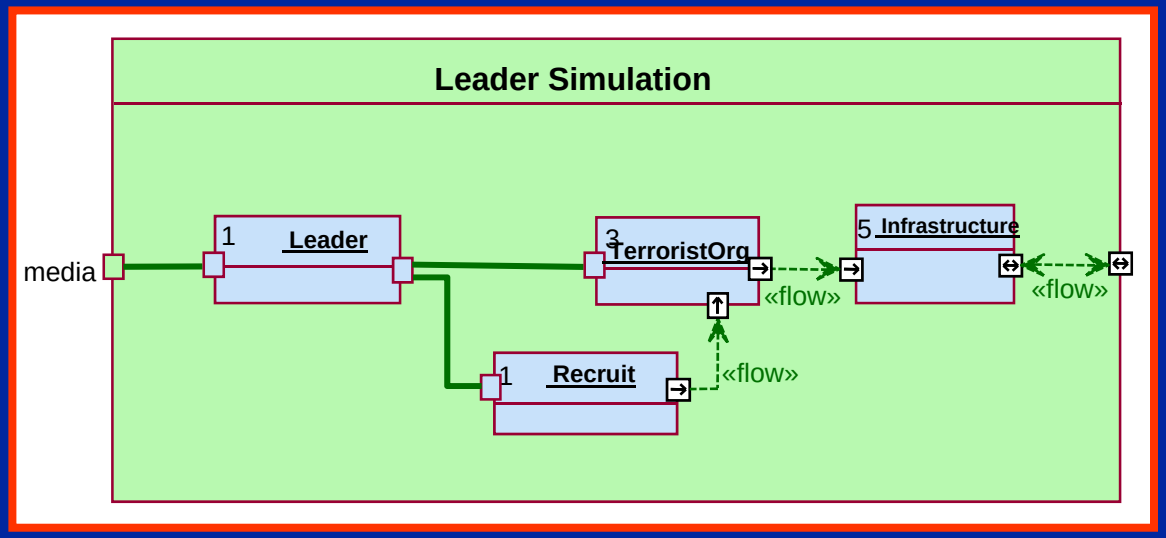
SysML Structural Models; Relationships and Data Flow



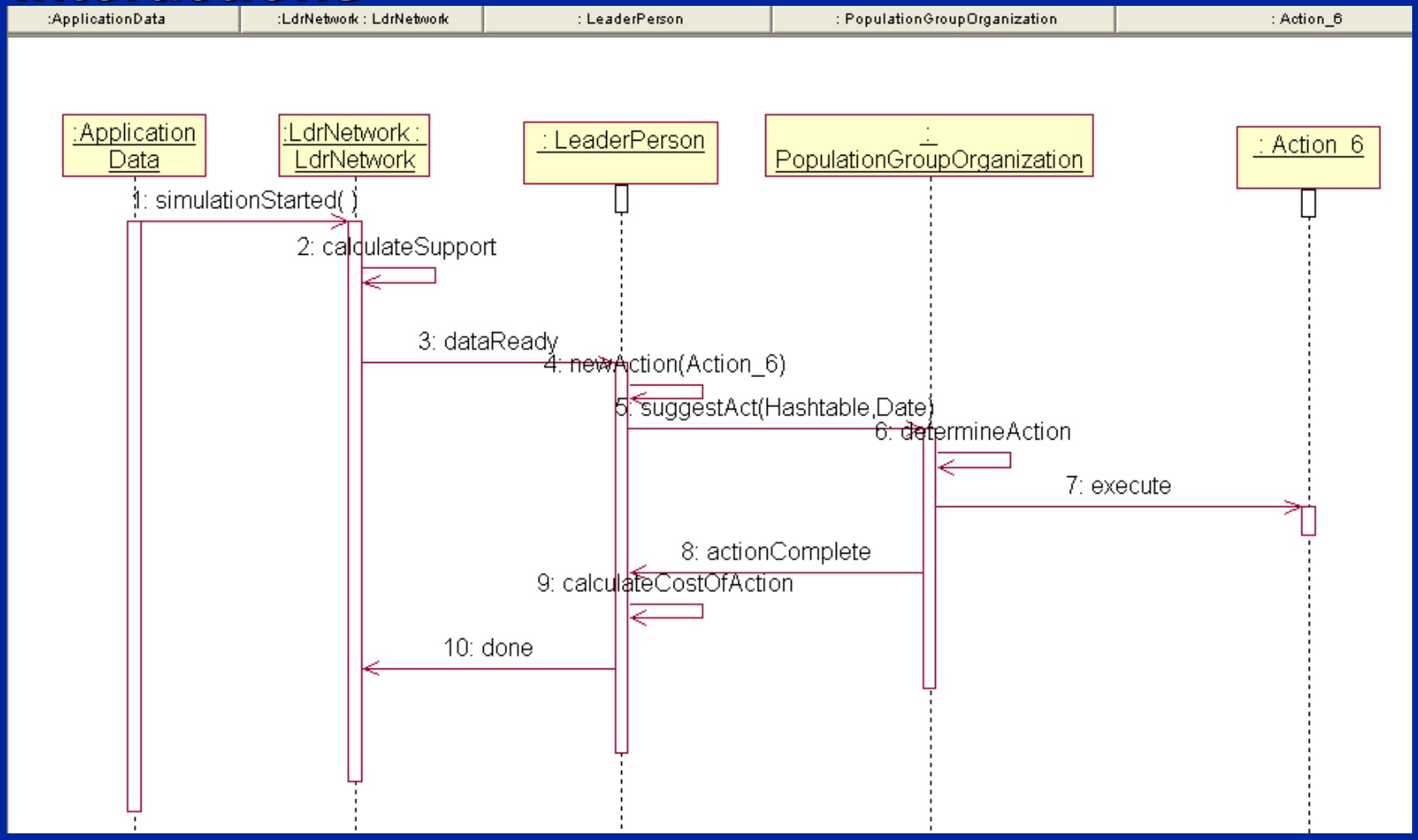
SysML Block Definition Diagram (BDD) is used to capture the components of the composable simulation.

The BDD can also be used to visualize the entity and model relationships that are now captured as Ontology Networks.

Use the Internal Block Diagram (IBD) to capture the flow of data and messages between the entity models.

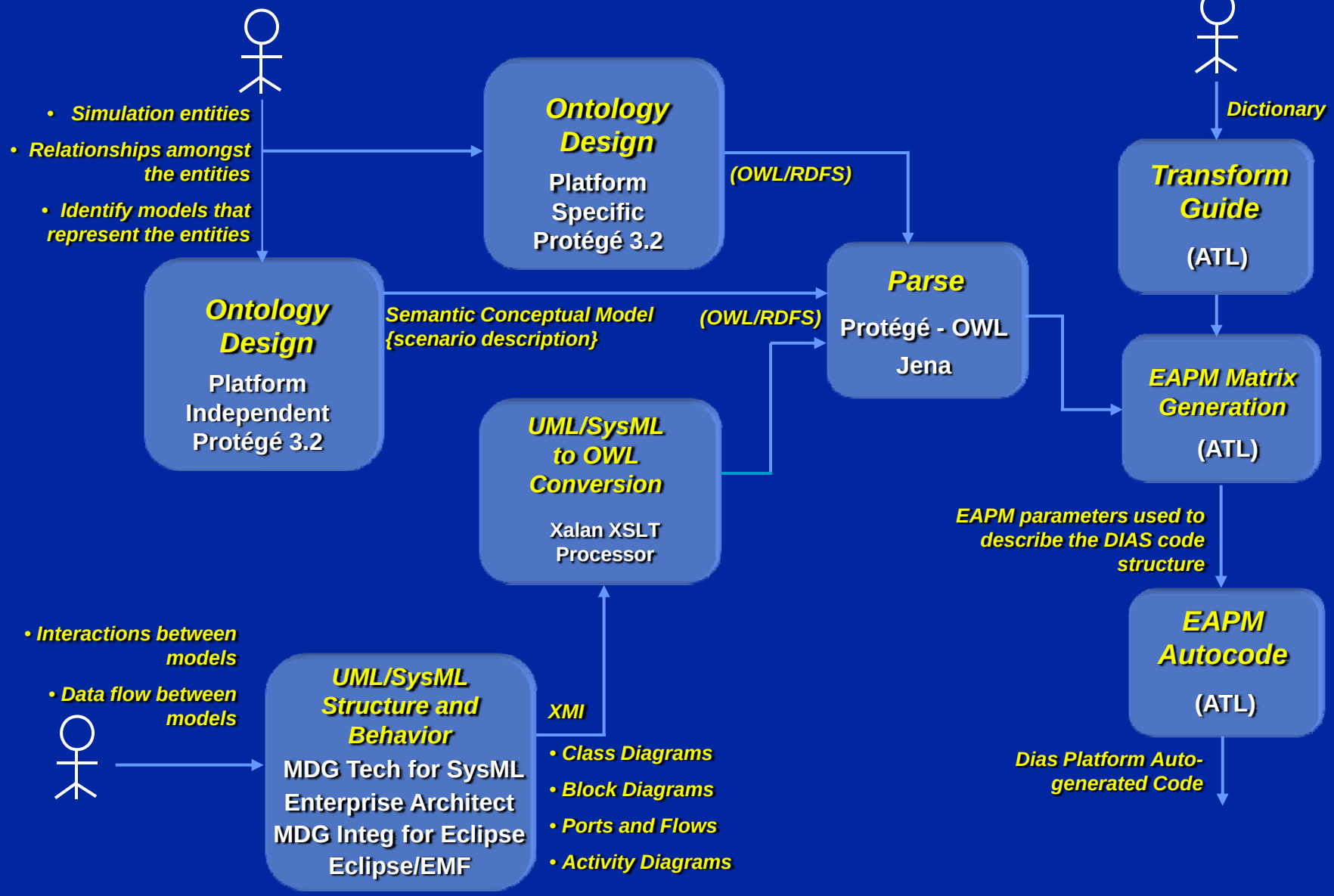


Integrated Model Sequence Diagram; Entity Interactions

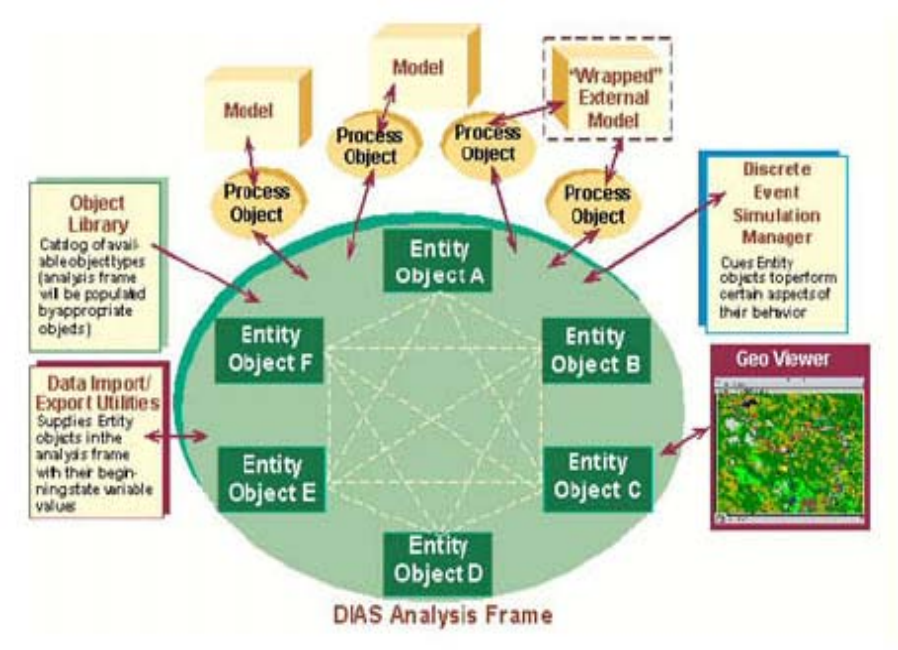


After importing ontology into SysML tool, Sequence Diagram data is used to provide information on execution flow and event generation

System Implementation



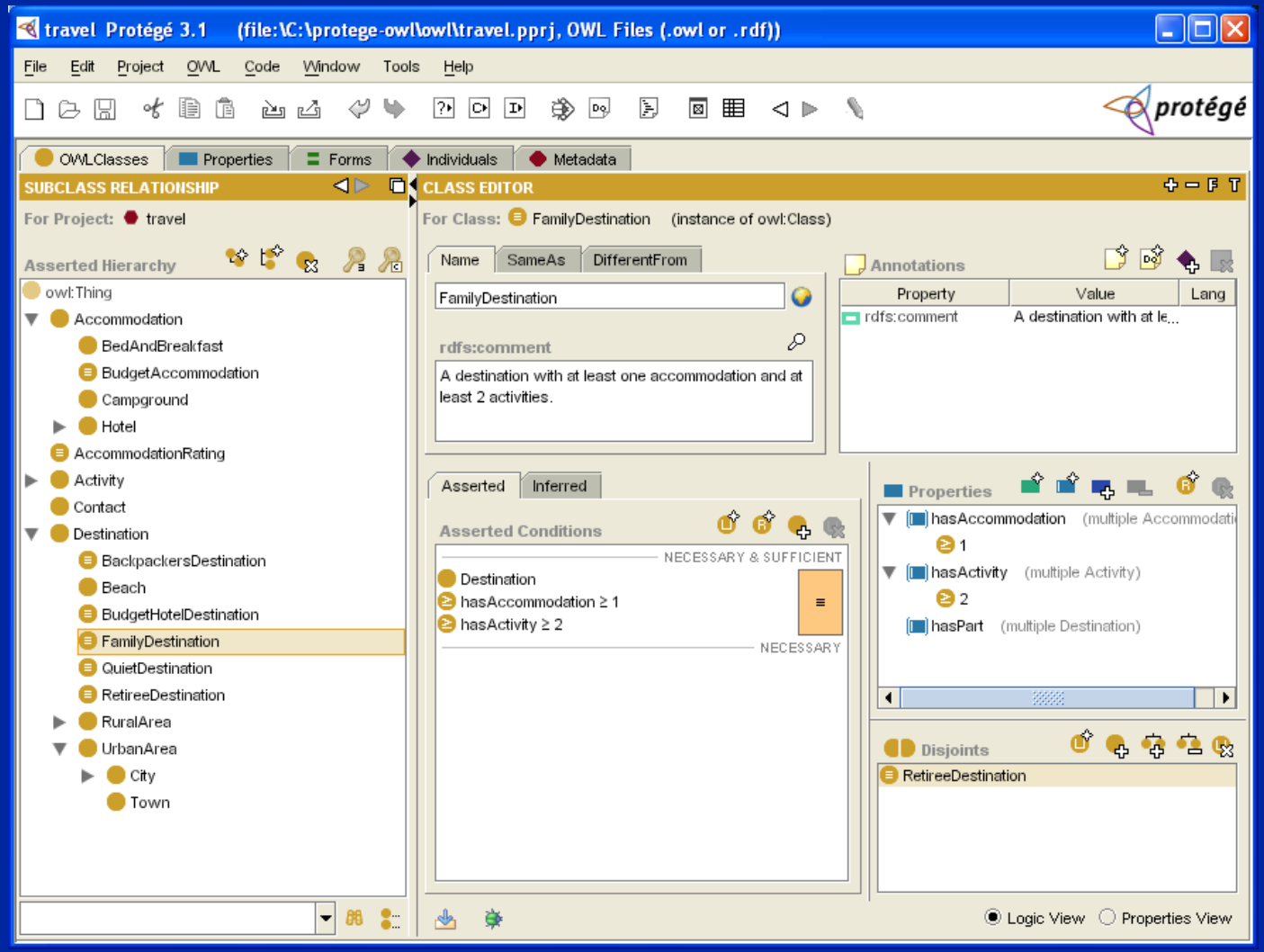
DIAS Architecture Representing Simulation Platform



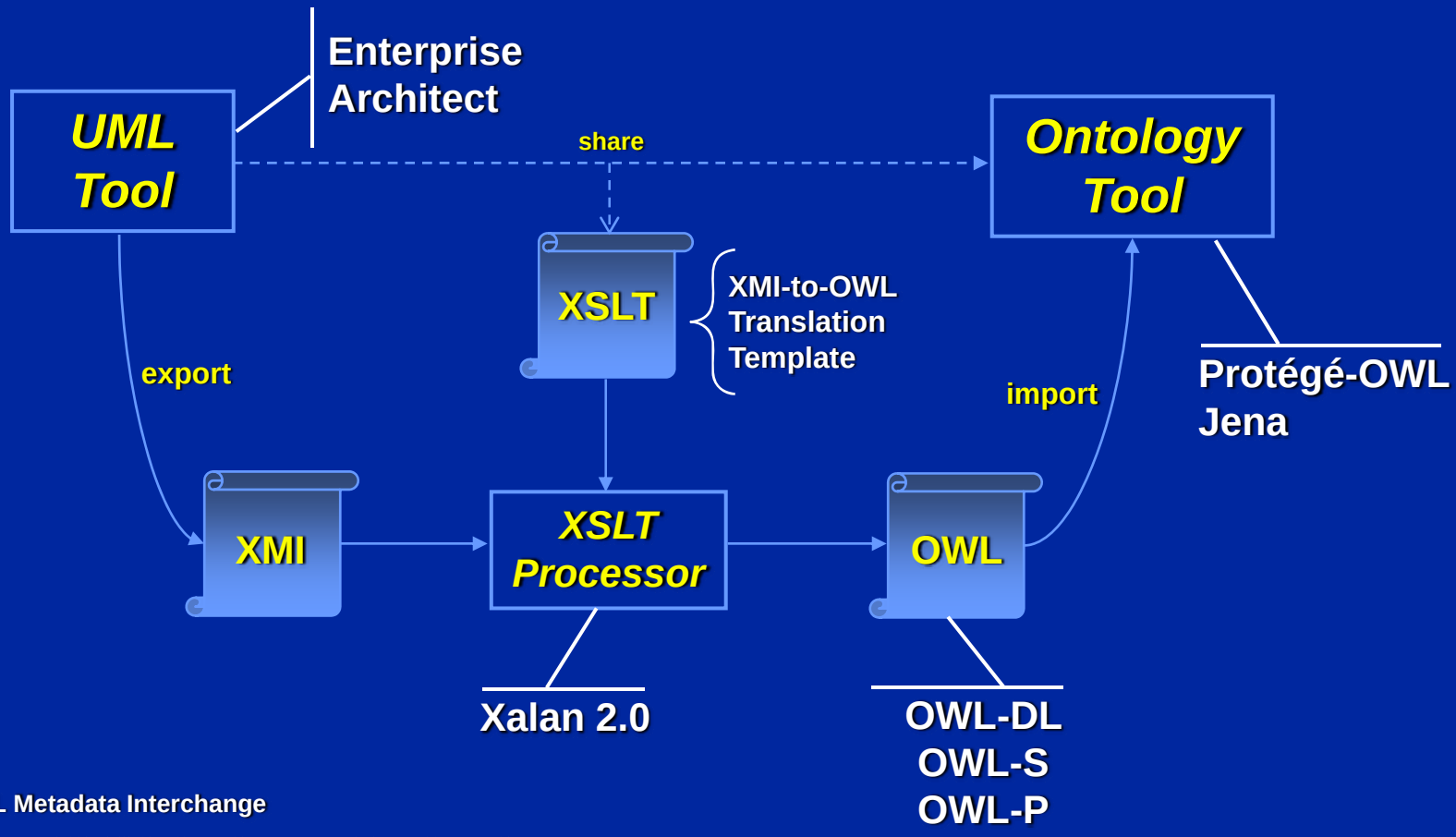
- DIAS (Dynamic Information Architecture System: Argonne National Laboratory)
  - Uses the "EAPM" to define how the models are integrated
- Entities: People places or things to be modeled
- Aspects: Specific behaviors of the Entities
- Process: Linkage of a behavior to a particular model
- Model: Code that communicates and runs a model

There is great regularity to the EAPM structure that is very amenable to autocoding

Ontology Capture of Entity/Model Relationships with Protégé-OWL



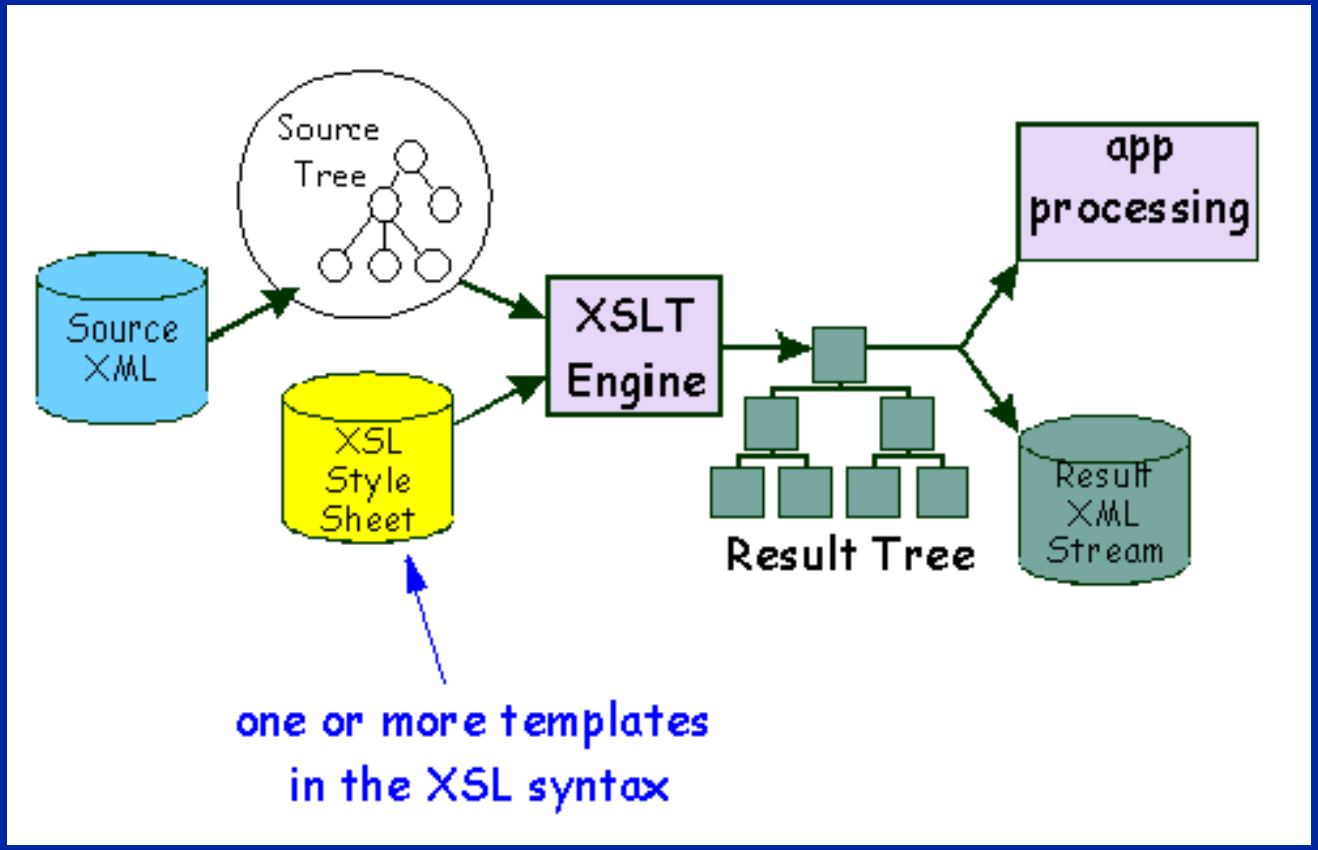
Transform UML to OWL in order to Extract Interaction Info



XMI – XML Metadata Interchange

XSLT – Extensible Stylesheet Language Transformations

Xalan 2.0; Used to Translate from XMI to OWL-S

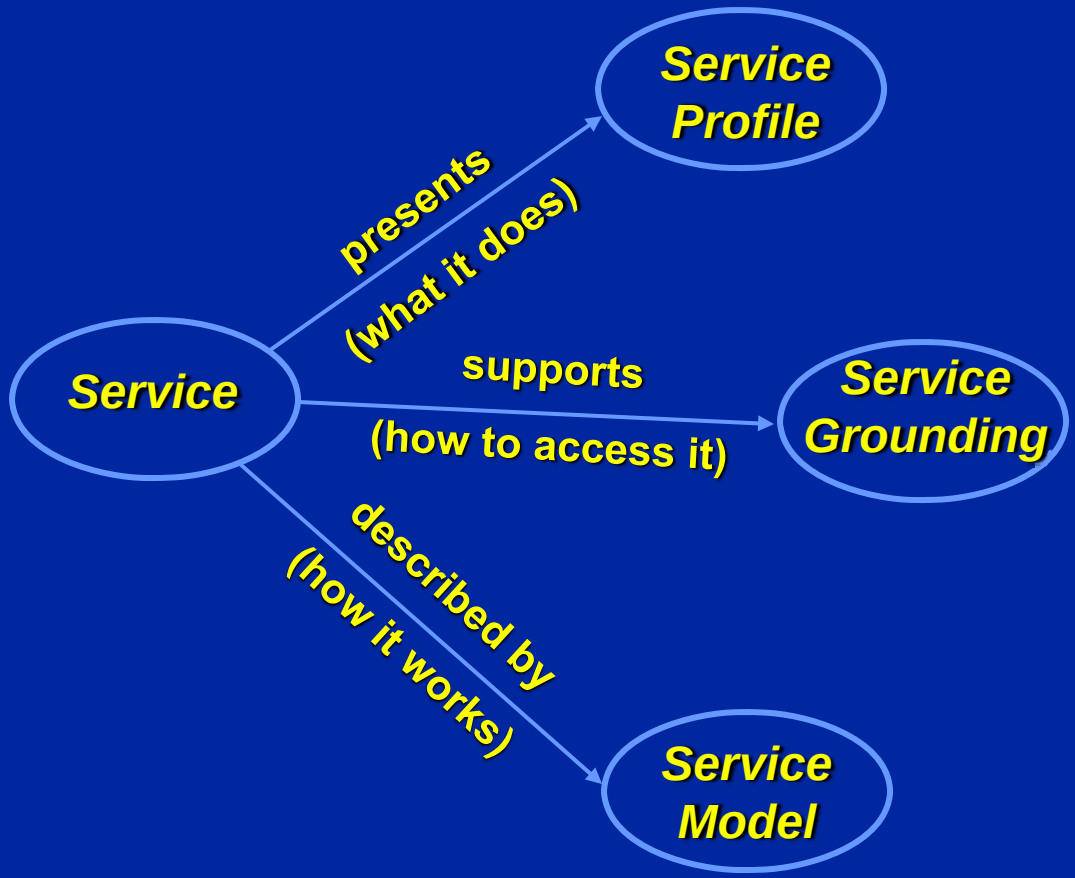


Example of XMI-to-OWL-S Translation Template

UML	XMI	OWL-S
Action	<UML2:Activity>	Process
Pin	<UML2:InputPin>	Input
Pin	<UML2:OutputPin>	Output
Pin to Pin	<UML2:ActivityEdge>	{In|Out}put Binding
Tagged Value	<UML:TaggedValue> <UML:Stereotype name='categoryName'>	categoryName
Tagged Value	<UML:TaggedValue> <UML:Stereotype name='taxonomy'>	taxonomy
Tagged Value	<UML:TaggedValue> <UML:Stereotype name='serviceName'>	serviceName
Tagged Value	<UML:TaggedValue> <UML:Stereotype name='textDescription'>	textDescription
Constraint	<UML:Constraint> <UML:Stereotype name='preCondition'>	Precondition
Constraint	<UML:Constraint> <UML:Stereotype name='Result'>	Result
Constraint	<UML:Constraint> <UML:Stereotype name='Effect'>	Effect
Sequence	<UML2:ActivityEdge>	Sequence
Fork	<UML2:ForkNode>	Split
Fork+Join	<UML2:ForkNode> <UML2:JoinNode>	Split+Join
Decision	<UML2:DecisionNode> <UML:Stereotype name='Choice'>	Choice
Decision	<UML2:DecisionNode> <UML:Stereotype name='If-Then-Else'>	If-Then-Else
Decision	<UML2:DecisionNode> <UML:Stereotype name='Repeat-Until'>	Repeat-Until
Decision	<UML2:DecisionNode> <UML:Stereotype name='Repeat-While'>	Repeat-While
Operation	<UML2:Message>	Process
Synchronous	<UML2:Message messageSort='synchCall'>	Sequence
Asynchronous	<UML2:Message messageSort='asynchCall'>	
Interaction Fragment(alt)	<UML2:CombinedFragment interactionOperator = 'alt'> <UML:Stereotype name='If-Then-Else'>	If-Then-Else
	<UML2:CombinedFragment interactionOperator = 'alt'> <UML:Stereotype name='Choice'>	Choice
Interaction Fragment(loop)	<UML2:CombinedFragment interactionOperator = 'loop'> <UML:Stereotype name='Repeat-While'>	Repeat-While
	<UML2:CombinedFragment interactionOperator = 'loop'> <UML:Stereotype name='Repeat-Until'>	Repeat-Until
Interaction Fragment(par)	<UML2:CombinedFragment interactionOperator = 'par'> <UML:Stereotype name='Split+Join'>	Split+Join
	<UML2:CombinedFragment interactionOperator = 'par'> <UML:Stereotype name='Any-Order'>	Any-Order

Example is taken from "Describing Semantic Web Services: From UML to OWL-S", Kim and Lee, 2007 IEEE International Conference on Web Services

OWL Service Ontology



EAPM Generator: Entity Interface

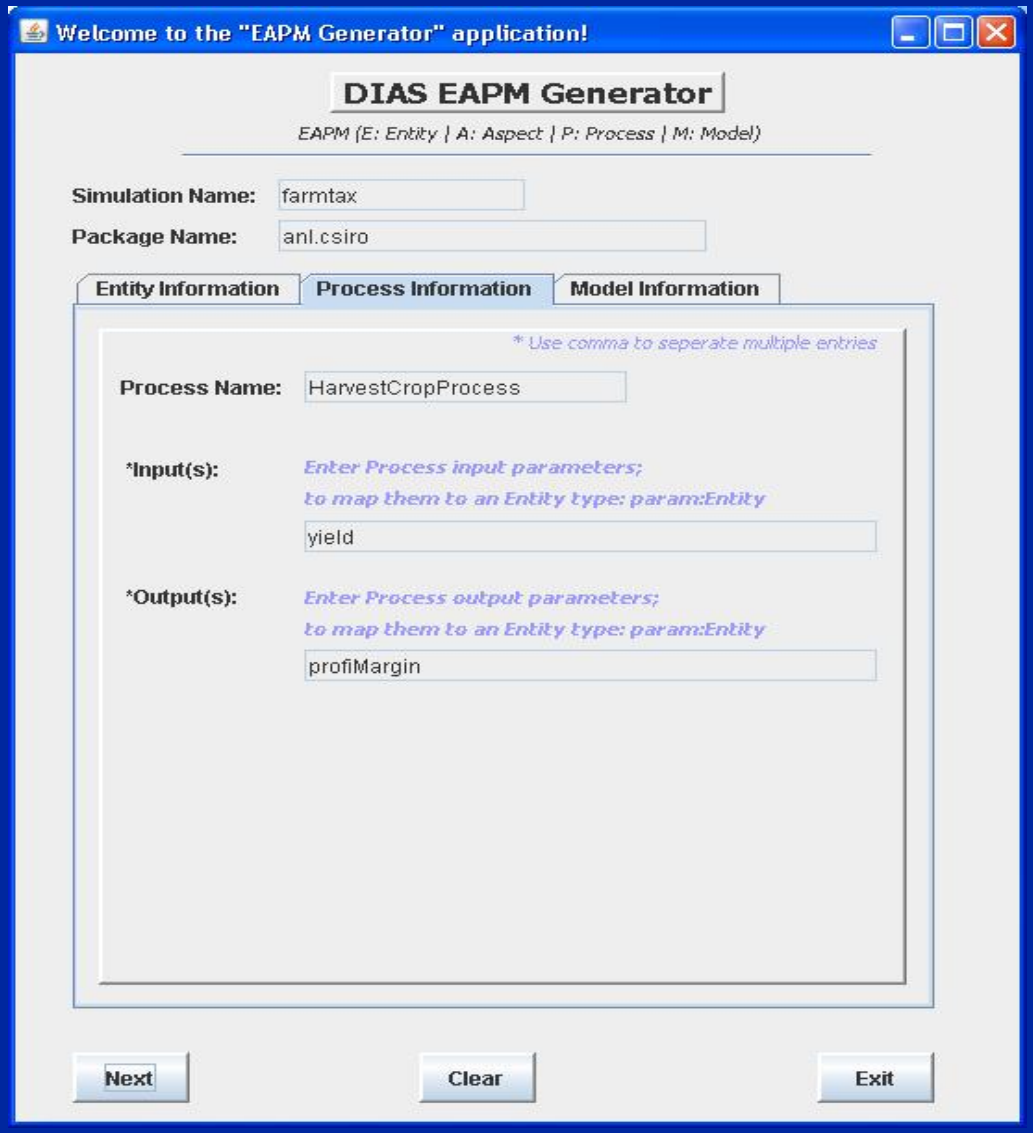
Information displayed (extracted from the UML/SysML) for an Entity:

1. Name
2. COA name, if part of one
3. Attributes (or parameters)
4. Aspects (or behaviors)
5. Events emitted (or sent)
6. Events received
7. Event data name
8. Event handlers
9. Events scheduled
10. Number of associated processes

"Next" Button:

- Once the user fills the form and presses "Next," the entity ".java" code will be auto-generated under the indicated package name directory structure

EAPM Generator: Process Interface



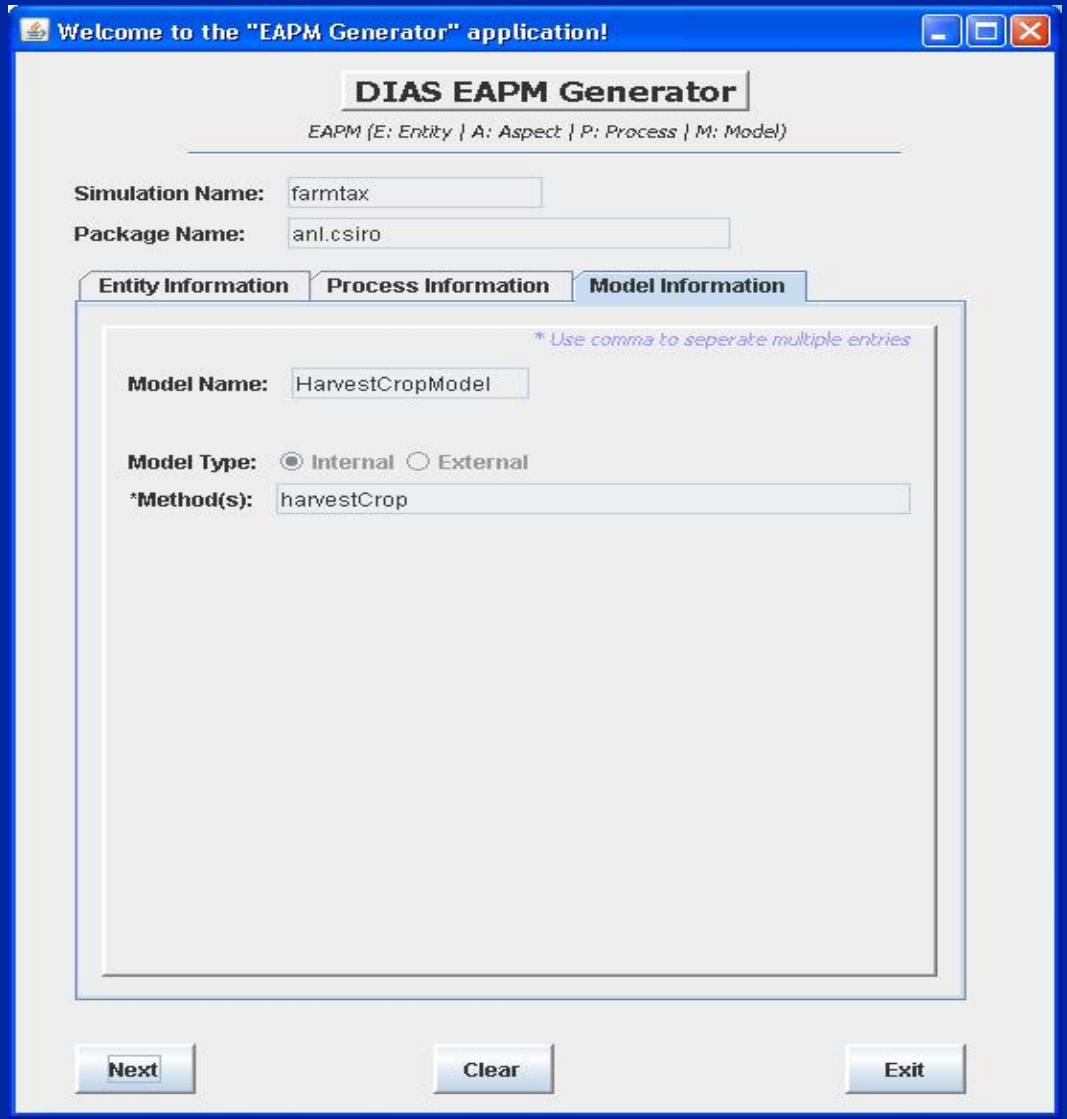
Information displayed (extracted from the UML/SysML) for a Process:

1. Name
2. Input parameters
3. Output parameters

"Next" Button:

- Once the user fills the form and presses "Next," the process ".java" code will be auto-generated under the indicated package name directory structure

EAPM Generator: Model



Information displayed (extracted from the UML/SysML Model:

1. Name
2. Is the model Internal or External?
3. Model method of interest

"Next" Button:

- Once the user fills the form and presses "Next," the model ".java" code will be auto-generated under the indicated package name directory structure

Products

- **Platform Independent Model (PIM) Related**
  - **OWL and SySML**
    - » Conceptual Model augmented with behaviors, actions and effects
    - » Model Integration Design Capture Process
    - » OWL to SySML Translation Processes
    - » Approach to capturing COA (action, node, effect triple plus temporal aspects)
- **Simulation Experimentation Related**
  - **"EAPM Generator": Simulation skeleton auto-coding tool and COA definition (OWL/SySML to DIAS translation)**
  - **"What-If" Experimentation User Interface**